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(54) Ultrasonic cleansing

(57) A method of cleaning a surface of an underwater structure, in which focussed beams of acoustic energy are directed at a surface to be cleaned with an energy level sufficient to cause cavitation of the water adjacent the surface and/or direct mechanical disruption at the surface, thereby dislodging matter to be removed. In one embodiment a part-spherical array (1) of acoustic transducers (2) is arranged to direct the beams to a common focus (4). In an alternative embodiment, separate focussing means may be used with a flat array. An array may be hand held or mounted to an underwater vehicle. Part-cylindrical or parabolic arrays may also be used.

The method is useful for cleaning subsea structures, e.g. oil rigs, at below 15 metres depth.

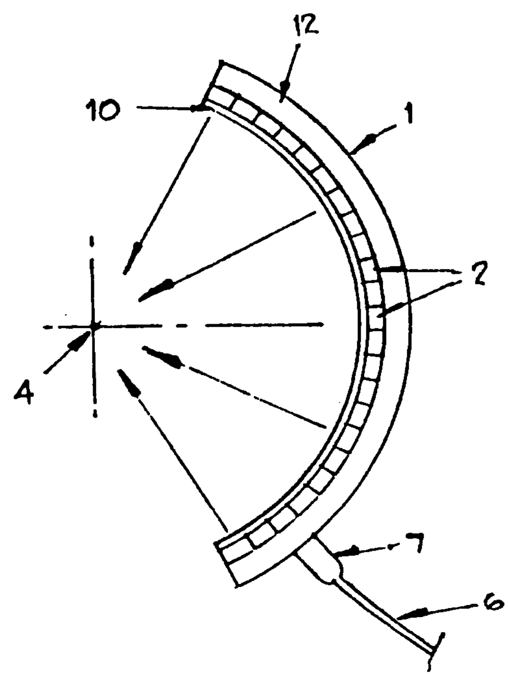

FIG 2.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.
This print reflects (an) amendment(s) to the request for grant effected pursuant to Rule 35 of the Patents Rules 1982.

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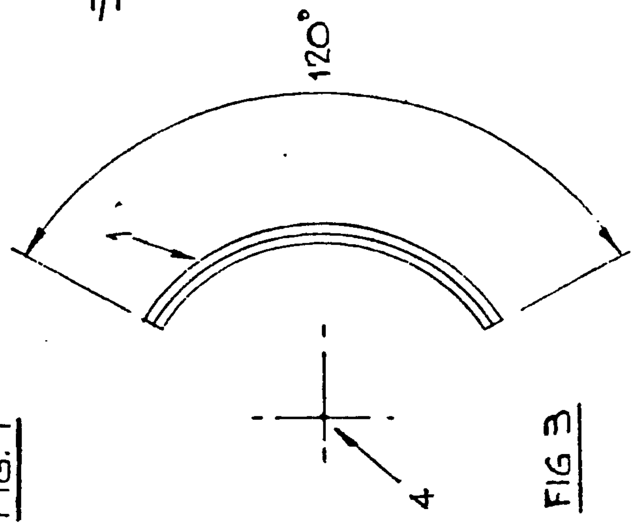

FIG 3

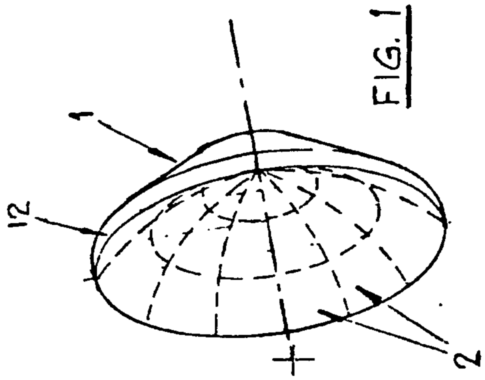

FIG. 1

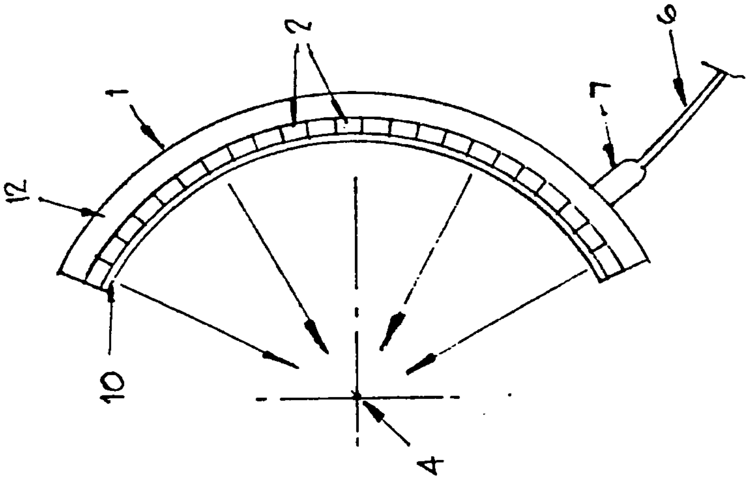

FIG 2.

SPECIFICATION

Ultrasonic cleaning

This invention relates to ultrasonic cleaning of surfaces and in particular to a method of such cleaning carried out under water, for example on subsea structures.

Ultrasonic or acoustic energy is used widely in applications in which the mechanical or physical effects of the wave vibrations are utilised as opposed to the other uses of sound energy in transmitting signals or information such as in echo-location. The mechanical or physical effects of ultrasound are used for example for making emulsions of immiscible liquids, for medical treatment, for plastics welding, and for cleaning of objects.

Ultrasonic cleaning is carried out in a tank in which components to be cleaned are immersed in a cleaning liquid (clean water, acidic or alkaline solutions or organic liquids) and ultrasonic vibrations are passed through the liquid throughout the tank so that the resulting shock waves produced during cavitation caused by the ultrasound reach all the solid surfaces of the components and have the effect of a scouring or scrubbing action on those surface.

Such known cleaning methods are confined to relatively small items and components which can be placed in a tank and immersed in the cleaning fluid.

The present invention is concerned with the cleaning of underwater structures which may be very large and which are fixed or are otherwise not capable of being placed or isolated in a tank, such as subsea oil drilling rigs.

According to one aspect of the present invention there is provided a method of cleaning the surfaces of an underwater structure, comprising directing and focussing one or more beams of acoustic energy at the surface to be cleaned of an energy level such as to cause cavitation adjacent the matter which is to be removed from the surface or such as to cause direct mechanical disruption of the matter to be removed, whereby that matter is detached or loosened from the surface.

The focussing of the energy on the one hand enables the cleaning effect to be concentrated in a specific region on the surface to be cleaned, and on the other hand enables the cleaning to be carried out in situ in the underwater environment beyond the confines of tank cleaning. This is possible because the energy generator and focussing means developed for the method of the invention can readily be located almost anywhere that it is required.

The energy levels are such as to enable marine encrustation or corrosion or old protective coatings to be removed from the surfaces of subsea structures for the purpose of inspection of or renewing of protective coatings on the cleaned surface. It is envisaged that energy levels of around 0.5 Kilowatt per square centimetr would be adequate, with frequency levels in the range 40 KHz to 250 KHz, though the energy and frequency levels required may vary widely depending upon different conditions.

At such energy levels the cleaning action would occur either by cavitation or by direct mechanical disruption, or by a combination of both these effects. Cavitation occurs when, at the appropriate energy levels the rarefaction of the water through which the acoustic wave travels leads to the formation of bubbles which subsequently collapse or implode under the action of ambient pressure and surface tension, and the resultant shock wave dislodges the matter on the surface. With direct mechanical disruption the acoustic vibration in the water itself is sufficiently forceful to dislodge the matter.

Since the ambient pressure affects the degree and force at which cavitation occurs, it will be appreciated that the actual frequency and energy levels employed will have to be varied depending upon the depth in the water at which the cleaning is to be carried out. This will also affect the rate of cleaning, and in any given location it may be necessary to alter the balance between cavitation and mechanical disruption to achieve optimum results.

It is expected that the focussed energy cleaning will be sufficient in itself to clean most surfaces. Therefore, additional procedures such as pre-treatment or simultaneous or subsequent mechanical abrasion would not normally be needed for most cases though these additional procedures could be used as well, if required.

In a preferred embodiment, the acoustic energy is generated using a focussed array of acoustical transducers. The array of transducers may be arranged in a part-spherical, part-cylindrical or other geometrical arrangement so as to focus the beams of acoustic radiation at a point, line or region; or the transducers may be arranged in an arrangement which does not in itself focus the beams (such as a flat plate arrangement) but which is used with separate focussing means.

In use, the array or array and focussing means is positioned to cause cavitation or mechanical vibration close to the surface to be cleaned. The array is moved to progress the cleaning action for example by a traversing or a scanning action over the surface. The excitation of the array is controlled as required to maintain the cleaning action at the required depth.

It will be appreciated that by providing a focussing arrangement for the acoustic energy whereby the cleaning action can be concentrated selectively at a specific region more versatile cleaning can be carried out than has hitherto be possible with ultrasonic cleaning.

Wher obj cts are ultrasonically cleaned in a tank, the vibration energy treats all the exposed surfaces so that if parts of thos surfaces ar not to b cleaned, they would have to be specifically masked.

According to a further aspect of the invention, therefore, there is provided apparatus for acoustic cleaning of a surface within a liquid, comprising an array of acoustical transducers which are arranged in such a way as to direct the acoustical energy generated to a concentrated region. Alternatively, it might be conceivable to use one or more acoustical transducers and to have separate focussing means for concentrating the beams so produced.

Such apparatus could have use even in a tank where only a specific region of a surface is to be cleaned.

The apparatus could either be hand-held or manually positioned, or it could be carried by transport or other moving means such as a robot or controlled vehicle.

The invention may be put into practice in a number of ways but certain specific embodiments will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of an array of acoustical transducers in the form of a part-spherical dish, for use in underwater acoustic cleaning;

Figure 2 is a section through the dish of Figure 1; and

Figure 3 is a similar section showing an example of possible dimensions for one construction.

A particular object of the inventive cleaning method is for cleaning subsea structures such as oil-drilling rig/platform supports.

At present such structures or parts of them have to be cleaned by difficult mechanical abrasion, such as wire brushing, or chipping methods if inspection of the structural condition is to be carried out. Such methods are laborious and do not give entirely satisfactory results.

Other cleaning methods used at present include blasting with very high pressure water jets, sometimes with grit in the water of the jets, or employing explosives which are detonated near to or around the surface to be cleaned, the explosive force causing cavitation which dislodges the surface matter. For obvious reasons such methods involve considerable safety hazards and are therefore disadvantageous.

Chemical cleaning methods are not capable of being carried out in the sea or at such depths.

The method of the invention proposes to utilise the presence of the water surrounding the structure by adopting ultrasonic cleaning techniques using generating and focussing means which can be taken to the appropriate location and operated in situ.

One example of such a generating and focussing system is shown in the drawings. This comprises a part-spherical dish 1 composed of an array of individual acoustical transducers 2 arranged appropriately so as to be directed to a common centre or focus 4.

Th individual transducers 2 are electrically powered and may be either of the ceramic lectrostrictive type or of th magnetostrictive type. For power supply they are connected to a suitable electrical power supply line 6 provided with a waterproof connector 7.

Water proofing such as a rubber layer 10 is provided over the front of the transducers 2 to protect them from the effects of sea-water, and at the back of the dish 1, which back may comprise a part-spherical support shell or framework for the transducers 2 which also acts as a reflector to concentrate the beams generated by the transducers, there may be a layer of buoyancy material 12 to provide flotation to counterbalance the weight of the transducers and support shell. The buoyancy 12 may of course take other forms, for example a ring at the rim of the dish 1.

The rim of the dish 1 subtends an angle of 120° to the centre of curvature (the focus 4), and in one proposed construction a radius of 300 mm is proposed giving a chordal width of the dish of 520 mm.

The tranducers 2 are designed to generate a selected single frequency, which may be adjustable, within the range 40 KHz to 250 KHz, and to provide an energy level of around 0.5 Kilowatt per square centimetre. If ceramic transducer elements are used, made of sintered ceramic material with piezo electric characteristics, these may be loaded with metal faces to obtain lower resonant frequencies.

Apart from the focussing of the energy as proposed in the invention, the use of ultrasound for cleaning at significant water depths involves a significantly more intense cleaning action compared with merely using ultrasonic vibration in a tank, because of the pressures which prevail. The method of the invention is proposed for use at depths of from 15 to 1000 metres, i.e. at water pressures of from 22 p.s.i. to over 1300 p.s.i. At such pressures the effect of both the cavitation caused by the acoustic waves and the mechanical or physical vibration in combination with the effect of the focussed energy, will be very considerable. The exact frequency and energy output required will, or course, depend upon the depths and other factors such as the nature of the surface matter to be removed, and those can be varied so as to obtain the optimum cleaning effect with either cavitation and/or mechanical disruption of the dirt or other matter to be removed.

In use, the dish 1 would be mounted as an integral fit at the front of a remotely controlled vehicle programmed or selectively controlled to progress or scan over a given area of the

surface to be cleaned, maintaining fairly clos ly the focussing distanc from the surface so that the acoustic vibrations, automatically focussed by virtue of the geometry of the dish 1, are concentrated just at or slightly in front of or behind the surface being cleaned.

The cleaning can, of course, be carried out readily on surfaces which it would be virtually impossible to clean directly such as hidden or inaccessible areas.

In other cases, the dish 1 could be mounted on a hand-held diver's unit or on a robot.

It is envisaged that all types of surface coating matter can be removed, such as marine encrustation, corrosion or an old protective coating, so as to reveal the clean basic surface material. Probably, no pre-treatment or accompanying mechanical abrasion will be needed with the acoustic cleaning though the use of these is not excluded if appropriate.

Once cleaned, the surfaces would be treatable as for normal follow-up actions of protecting bare surfaces left by any cleaning process.

It will be appreciated that the geometry of the focussing array of the transducers may be other than part-spherical as shown in the drawings. For example a part-cylindrical array could be used to give a line focus, or with other types of acoustic transducers it might be feasible or necessary to use geometries of varying radius, e.g. parabolic, with or without separate focussing means; or to use a non-focussing arrangement, e.g. flat, but with separate focussing means.

Whilst reference has been made to the cleaning of oil-rigs, the method is applicable to cleaning of other subsea installations, or of ships, or of such structures in freshwater rather than subsea.

CLAIMS

1. A method of cleaning a surface of an underwater structure, comprising directing one or more beams of acoustic energy at the surface to be cleaned of an energy level such as to cause cavitation adjacent matter which is to be removed from the surface and/or such as to cause direct mechanical disruption of the matter to be removed, whereby that matter is detached or loosened from the surface.

2. A method as claimed in claim 1, wherein the acoustic energy is generated using one or more acoustical transducers.

3. A method as claimed in claim 1 or claim 2, in which the beam or beams of acoustic energy are focussed or concentrated at a point, line or region at or adjacent the surface to be cleaned.

4. A method as claimed in claim 3, in which the acoustic energy is generated using an array of acoustical transducers, which array is arranged to dir ct the output energy transmissions to a common point, lin or region.

5. A method as claimed in claim 4, wherein the array or transducers is arranged in a part-spherical part-cylindrical or other geometrical arrangement.

6. A method as claimed in any one of claims 1 to 3, wherein separate focussing means are used to focus the beam or beams of acoustic energy.

7. A method as claimed in any one of the preceding claims, in which the beam or beams of acoustic energy are tra versed or scanned over the surface of the structure being cleaned.

8. A method as claimed in any one of the preceding claims, wherein the structure is at a depth underwater such that the water pressure substantially contributes to the force of cavitation caused.

9. A method as claimed in any one of the preceding claims, when carried out at a water depth below 15 metres.

10. A method as claimed in any one of the preceding claims, in which an energy level of 0.5 Kilowatt per square centimetre of the surface to be cleaned is used, with frequency levels in the range 40 KHz to 250 KHz.

11. An array of acoustical transducers for use in cleaning a surface of an underwater structure, comprising a concave dish composed of an array of individual acoustical transducers arranged so that beams of acoustic energy generated from the individual transducers are directed to a common focus.

12. An array as claimed in claim 11, in which the individual acoustical transducers are mounted on a support shell or framework which acts as a reflector.

13. An array of acoustical transducers for use in cleaning a surface of an underwater structure, comprising an arrangement of individual transducers and separate focussing means for concentrating the output transmissions of the transducers at a common point, line or region.

14. An array as claimed in any one of claims 11 to 13, wherein the acoustical transducers are electrically powered and are of a ceramic electrostrictive or magnetostructure type.

15. An array as claimed in any one of claims 11 to 14, wherein a water-proof layer is provided over the front surface of the dish to protect the acoustical transducers from water.

16. An array as claimed in any one of claims 11 to 15, further including, buoyancy material.

17. An array as claimed in any one of claims 11 to 16, in combination with means for traversing or scanning the surface to be cleaned.

18. A method of cleaning a surface of an underwater structure, substantially as hereinbefore described with reference to the accompanying drawings.

19. An array of acoustical transducers for

use in a method of cleaning a surfac of an underwater structur , substantially as hereinbefore described with reference to the accompanying drawings.

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